BENNETT RESOURCES

Valhalla Gas Exploration and Appraisal Program

Groundwater Management Plan

BNR_HSE_MP_015

VERSION HISTORY				
Ver. No.	**Ver. Date**	**Author**	**Reviewer**	**Revision**
1	10 Jan 2022	TN, AF	SR	Draft
2	01 Jul 2023	MLL, AF	ML	Final
3	26 Apr 2024	MLL, AF	ML	Final

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Acronym / abbreviation / definition

Terms / acronym	Definition / expansion
AER	Annual Environmental Report
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
Baseline groundwater monitoring	Refers to the measurement of groundwater levels and collection of groundwater samples to determine water quality prior to the commencement of proposed activities
BNR	Bennett Resources Pty Ltd
DEMIRS	(WA) Department of Energy, Mines, Industry Regulation and Safety (from 1 Dec 2023)
DMIRS	Former (WA) Department of Mines, Industry Regulation and Safety, now DEMIRS
DMP	Former (WA) Department of Mines and Petroleum; now DEMIRS
DoW	Former (WA) Department of Water; now DWER
DWER	(WA) Department of Water and Environmental Regulation
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
e.g.	For example
EP 371	Exploration Permit 371
EP Act	(WA) Environmental Protection Act 1986
EPA	(WA) Environmental Protection Authority
ERD	Environmental Review Document
GDE	Groundwater Dependent Ecosystems
GWMP	Groundwater Management Plan
ha	Hectare
HFS	Hydraulic Fracture Stimulation
i.e.	That is
kL	Kilolitres
km	Kilometres
km^2	Square kilometres
m	Metres
ML	Megalitres
Proposal	Valhalla Gas Exploration and Appraisal Program
QA/QC	Quality Assurance / Quality Control
SD	Standard Deviation
Surveillance groundwater monitoring	Refers to monitoring that occurs after commencement of an activity and is not considered to be representative of 'baseline 'conditions. Any data collected after commencement of a petroleum activity should be directly compared to baseline data and relevant standards to determine whether changes have occurred
WA	Western Australia

Terms / acronym	Definition / expansion
~	Approximately

1 Executive summary

This Groundwater Management Plan (GWMP) has been prepared by Bennett Resources (BNR) to support the assessment, approval and implementation of the Valhalla Gas Exploration and Appraisal Program (the Proposal) under Part IV of the *Environmental Protection Act 1986* (EP Act).

Bennett Resources referred the Proposal to the Environmental Protection Authority (EPA) under Part IV of the EP Act on 24 December 2020 (EPA Assessment Number 2281). The EPA has decided to assess the Proposal as Public Environmental Review. The Environmental Review Document (ERD) is to include environmental impact assessment (EIA) and management information, including this environmental management plan (EMP), which will be subject to an eight-week public review period.

This GWMP has been written in accordance with the guideline "Instructions on how to prepare Environmental Protection Act 1986 Part IV Environmental Management Plans" (EPA 2021). An executive summary of this GWMP is provided in Table 1-1.

Table 1-1: Executive summary of the GWMP

Proposal title	Valhalla Gas Exploration and Appraisal Program (EPA Assessment Number 2281)
Proponent name	Bennett Resources Pty Ltd
Ministerial Statement number	The Proposal is currently being assessed by the EPA (Assessment 2281) and a Ministerial Statement and associated proposal implementation conditions are yet to be issued.
Purpose of the GWMP	The purpose of this GWMP is to detail the monitoring requirements along with response actions for trigger and threshold criteria that are required for the Proposal.
EPA key environmental factor and objective, and GWMP outcomes	**Inland Waters – EPA objective:** *To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.* GWMP outcomes: • no long-term changes to groundwater levels • no short or long-term changes to groundwater quality.
Condition clauses	No Ministerial Statement at the time of preparing the GWMP.
Key components in the GWMP	The key components of this GWMP are: • baseline groundwater monitoring: which refers to the measurement of groundwater levels and collection of groundwater samples to determine water quality prior to the commencement of proposed activities. • surveillance groundwater monitoring: which refers to monitoring that occurs after commencement of an activity and is not considered to be representative of 'baseline 'conditions. Any data collected after commencement of a petroleum activity should be directly compared to baseline data and relevant standards to determine whether changes have occurred. • trigger and threshold criteria and subsequent response actions • annual reporting (including results of monitoring).
Proposed construction / commencement date	TBC – within Calendar Year 2024.
EMP required pre-construction / commencement?	Yes ☒ No ☐

2 Context, scope and rational

2.1 Proposal

The Proposal is to complete an unconventional exploration and appraisal drilling and Hydraulic Fracture Stimulation (HFS) program within Petroleum Exploration Permit EP 371 (EP 371) in the Canning Basin, within the Shire of Derby / West Kimberley in Western Australia (WA). The intent of the Proposal is to evaluate the large tight gas resource in the region which has the potential to offer long-term energy security to Australia. The onshore Canning Basin is an early Ordovician to early Cretaceous aged geological basin that covers approximately 430,000 km^2 in the West Kimberley region. The Proposal is targeting hydrocarbons present from the Laurel through to the Devonian Formations, ranging from 2,000 m to 5,000 m below ground level. The main target is the Laurel Formation, with hydrocarbons present at depths between 2,000 m and 4,000 m below ground level. Table 2-1 provides a summary of the proposal.

Table 2-1: Summary of the Proposal

Proposal title	Valhalla Gas Exploration and Appraisal Program (EPA Assessment Number 2281)
Proponent name	Bennett Resources Pty Ltd (BNR)
Short description	The Proposal is to undertake an unconventional exploration and appraisal drilling program within EP 371, located in the Canning Basin, West Kimberley of Western Australia. The Proposal involves constructing up to 20 exploration wells within 10 well sites. The intent of the Proposal is to further explore and appraise the extent of the tight gas reservoirs present from the Laurel through to the Devonian Formations, at depths ranging from 2,000 m to 5,000 m below ground level. The exploration and appraisal program are expected to commence in 2024.

2.2 Key environmental factors

Two key elements have been identified as having the potential to affect the Key Environmental Factor – Inland Waters. These are:

- water abstraction for process water and camp supply
- gas exploration method (unconventional).

A summary of the Inland Waters environmental factor with a specific focus on these elements and subsequent impacts relating to this activity is included below in Table 2-2.

Table 2-2: Summary of key environmental factor – Inland Waters

EPA objective	To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.
Policy and guidance	• Environmental Key Factor Guideline – Inland Waters (EPA 2018) • Australian and New Zealand Environment and Conservation Council (ANZECC) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2018) • Department of Water – Water Quality Protection Notice 26 (liners for containing pollutants, using synthetic membranes) (DoW 2013) • Department of Mines and Petroleum (DMP) / Department of Water (DoW). Guideline for groundwater monitoring in the onshore petroleum and geothermal industry (DMP & DoW 2016).
Project activities	• water abstraction for process water and camp supply • gas exploration method (unconventional).
Environmental values / receptors	• Liveringa and Grant Group (including Poole Sandstone and Reeves) Aquifers • the Groundwater Dependent Ecosystem (GDE) Mount Hardman (associated with the Liveringa Aquifer) • other groundwater users (>18 km away from the Development Envelope).
Potential impacts – direct impacts	• changes to groundwater levels (groundwater drawdown) associated with water extraction • contamination of surficial aquifers due to lost circulation.

Potential impacts – indirect impacts	• contamination of aquifers through unplanned fracture heights • contamination of surficial aquifers from an accidental release at the surface of drilling fluids, HFS chemicals, liquid hydrocarbons or produced formation water.

2.3 Condition requirements

The Proposal is currently being assessed by the EPA (Assessment 2281) and a Ministerial Statement and associated proposal implementation conditions are yet to be issued. Should this Proposal be approved for implementation, any conditions relating to this GWMP will be included in this section.

2.4 Rationale and approach

This section provides a concise description of the rationale and approach for this Plan. Specifically, the following sub-sections summarise:

- the site-specific environmental values, existing and/or potential uses, ecosystem health condition or sensitive component of the key environmental factor which will be affected (Section 2.4.1)
- study findings (Section 2.4.3)
- key assumptions and uncertainties (Section 2.4.4)
- management approach (Section 2.4.5)
- rational for choice of indicators (Section 2.4.6).

2.4.1 Receiving environment

The Development Envelope is situated in the Canning Basin region within the Fitzroy River catchment. The Canning Basin is considered the second largest groundwater resource in Australia after the Great Artesian Basin. It is a large sedimentary basin covering an onshore area of more than 450,000 km^2 (DoW 2012). The major regional aquifer systems in the Canning Basin are (in order of decreasing age):

- Grant Formation
- Liveringa Formation
- Wallal Sandstone
- Broome Sandstone.

Data from three petroleum wells drilled within the Development Envelope by the previous operator of EP 371 provides a detailed two-dimensional cross section of the aquifers located within the Development Envelope. Specifically, the major aquifers that are present within the Development Envelope include the:

- Liveringa aquifer
- Grant Group (including the Reeves aquifer) and Poole Sandstone aquifers.

A detailed summary of these aquifers with reference to local data has been provided in the Environmental Review Document for the Proposal (BNR_HSE_MP_013) and has not been duplicated here. However, a summary of the values of these aquifers is provided in Table 2-3 and Table 2-4.

Water quality of the Liveringa aquifer within the Development Envelope is well understood given the sampling programs that have been conducted for previous petroleum activities within EP 371.

Data provided from the Yungngora Community (over the past 4 years) and Fitzroy Crossing public drinking water source area reserve have been used to inform the water quality of the Poole Sandstone aquifer. These were selected as they are the closest groundwater users that extract water for potable drinking purposes. The Poole Sandstone aquifer is hydrogeologically similar to and considered to be part of the Grant Group (which also includes the Reeves aquifer).

Information regarding the aquifer quality of the Liveringa and Grant Group/Poole Sandstone aquifers is provided in the ERD and has not been duplicated here.

Table 2-3: Summary of Liveringa Aquifer values

Aquifer	Liveringa
Recharge mechanism	Rainfall on outcrop areas
Connectivity with other aquifers	Limited – underlain by the Noonkanbah (shale) Formation that is considered an aquitard, and is ~357 m thick
Number of baseline samples and duration of program	At least 21 samples (per bore) over 5 years
Number of groundwater licences within the Development Envelope	4
Regional use	• unlicensed livestock bores • main roads • oil and gas.

Table 2-4: Summary of Grant Group Aquifer values

Aquifer	Grant Group (including Reeves) and Poole Sandstone
Recharge mechanism	Rainfall on outcrop and shallow outcrops (none present within the Development Envelope)
Connectivity with other aquifers	Limited – underlain by the Anderson (shale) Formation that is considered an aquitard and is ~184–279 m thick
Number of baseline samples and duration of program	At least 5 samples (per bore) over 3 years
Number of groundwater licences within the Development Envelope	One, however, there are no known extraction bores.
Regional use	• oil and gas operators • mining operators • main roads • unlicensed for uses such as livestock and domestic bores • potential tourist operations • Indigenous community bores.

2.4.2 Environmental outcomes

The overall purpose of this GWMP is to quantify the potential environmental impacts and risks associated with the Proposal activities on inland waters. In meeting this objective, BNR will be able to verify the outcomes of the ERD which state that the impacts and risks are not significant given the manner in which the Proposal is planned to be implemented.

Based upon the groundwater monitoring program selected for the Proposal (Section 3.1), an outcome-based approach has been selected given the ability to collect quantitative data that enables unbiased scientific analysis to be completed. Further to this, the quantitative groundwater indicators for this GWMP have been based on baseline regional and local data, enabling outcomes to be selected for the Proposal.

Consequently, the following outcomes have been defined for this GWMP:

- No long-term changes to groundwater levels
- No short or long-term changes to water quality.

2.4.3 Study findings

To inform the impact assessment associated with groundwater drawdown to other groundwater users and the Mount Hardman Creek GDE, BNR utilised a study by Rockwater (2016) that considered groundwater drawdown associated with HFS water abstraction within the Development Envelope. To complete the drawdown modelling,

Rockwater utilised Modflow Pro version 8.0.45, which incorporates MODFLOW, a groundwater modelling software designed by the US Geological Survey (McDonald and Harbaugh 1988). The model was set up with a rectangular grid of 57 rows, 57 columns and two layers covering an area of 5 km by 5 km centred on a single production bore. Layer 1 extends to 50 m depth, and Layer 2 to 170 m depth. Model cell sizes range from 25 m by 25 m near the production bore, to 100 m by 100 m in peripheral areas.

The model was set up initially with parameters that are typical of a minor aquifer such as the Liveringa but was calibrated with drawdown data observed during field monitoring. The model was run to predict groundwater level drawdowns arising from pumping a bore over a six-month period at the average rate required to produce 33,400 kL. The calculated drawdowns after six months of extraction are shown for each model layer in Figure 2-1. Modelling predicted that drawdowns of 1 m or more could extend up to 410 m from a production bore at the (deep) level of the screens in the production bore, but that there would be smaller drawdowns in the top 50 m of the Liveringa formation: 1.2 m close to the bore decreasing to 1 m at a distance of about 56 m from the bore, and 0.1 m at 690 m distance. Although the modelling is based on assumed parameters and the results are not unique, the calculated drawdowns are consistent with monitoring on the bores at the Valhalla North 1 and Asgard 1 well sites, where drawdowns at shallow depths (albeit with lower pumping rates) have been very small, and difficult to distinguish from normal seasonal fluctuations of about 0.2 to 1 m (depending on the frequency and magnitude of recharge events). For an overview of groundwater depth over the course of historic groundwater monitoring, refer to Appendix H of the Environmental Review Document (BNR_HSE_MP_013).

Using an extraction volume of 100,000 kL (100 ML) (which is the conservative maximum extraction for a Phase II well for the Proposal), the model predicted that a short-term drawdown of 1 m or more could extend up to 780 m from the extraction water bore at the (deep) level of the screens in the extraction bore (Rockwater 2016)). The model predicted that even with pumping for the maximum volume of 100 ML, groundwater levels would be expected to recover rapidly to within 0.2 m of baseline levels within hours of stopping extraction and to fully recover within weeks.

This model was not considered to be sophisticated enough and the potential for a drawdown of up to one metre raised concern through discussions with DWER. Therefore, additional modelling work was commissioned from Intera Geosciences Pty Ltd. MODFLOW 2005 was used to complete a detailed quantitative model to better understand groundwater drawdown. The Groundwater Vistas (ESI) modelling software was used to develop the input files, run the model executables and process model output. Two primary models were developed, one simulating the unconfined Liveringa Group (Mod 1) and one simulating the Grant/Poole aquifer system (Mod 2). A full explanation of the modelling approach is contained in annex to this management plan.

Model results are presented as mapped drawdown contours with a minimum contour of 0.2 metres and a 0.2 metre contour interval, which was chosen as normal seasonal fluctuations can range between 0.2 metres and one metre, so any values less than 0.2 metres are likely not significant relative to natural variations.

The modelled drawdown at the end of the six-month pumping period for Mod 1 showed the radius of the 0.2 metre drawdown contour was within 400 metres of each pumping bore, so would have no impact on any existing bores or groundwater systems.

The results from Mod 2 were similar, with predicted drawdowns of up to 0.4 metres, which is expected to be difficult to distinguish from normal seasonal variations in water levels of 0.2 – 1 metre (Rockwater, 2016).

Note, this means that the short-term drawdown will have less effect on the environment than seasonal fluctuations, given a maximum drawdown of between 0.2 and 0.4 metres and a recovery to 0.1 metre within one year of the cessation of pumping.

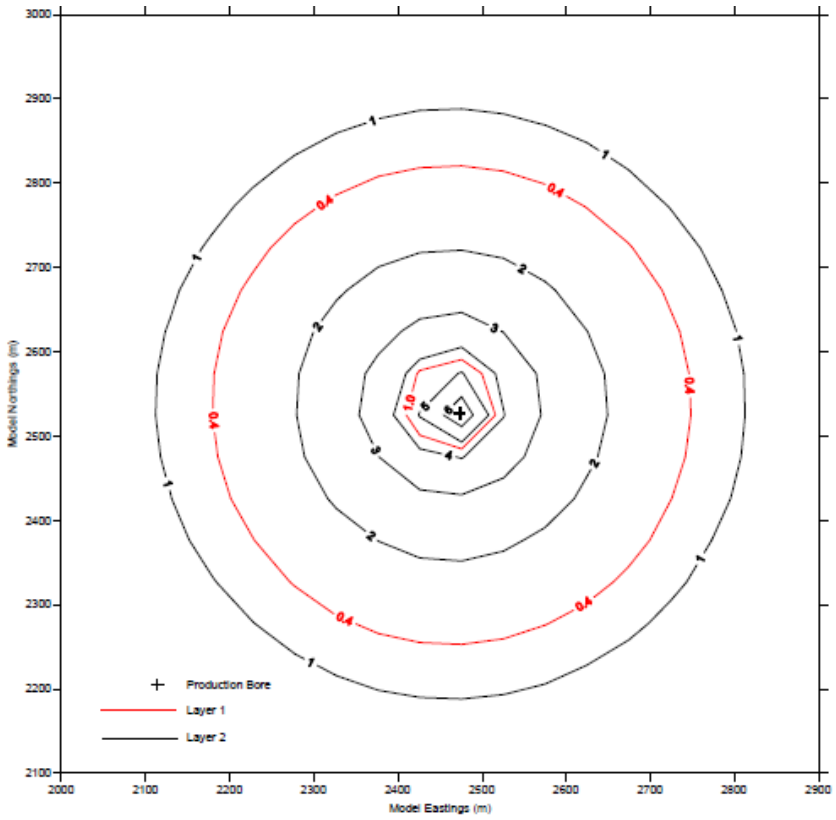

Figure 2-1 Drawdown contours associated with the extraction of 33,306 kL (Rockwater model)

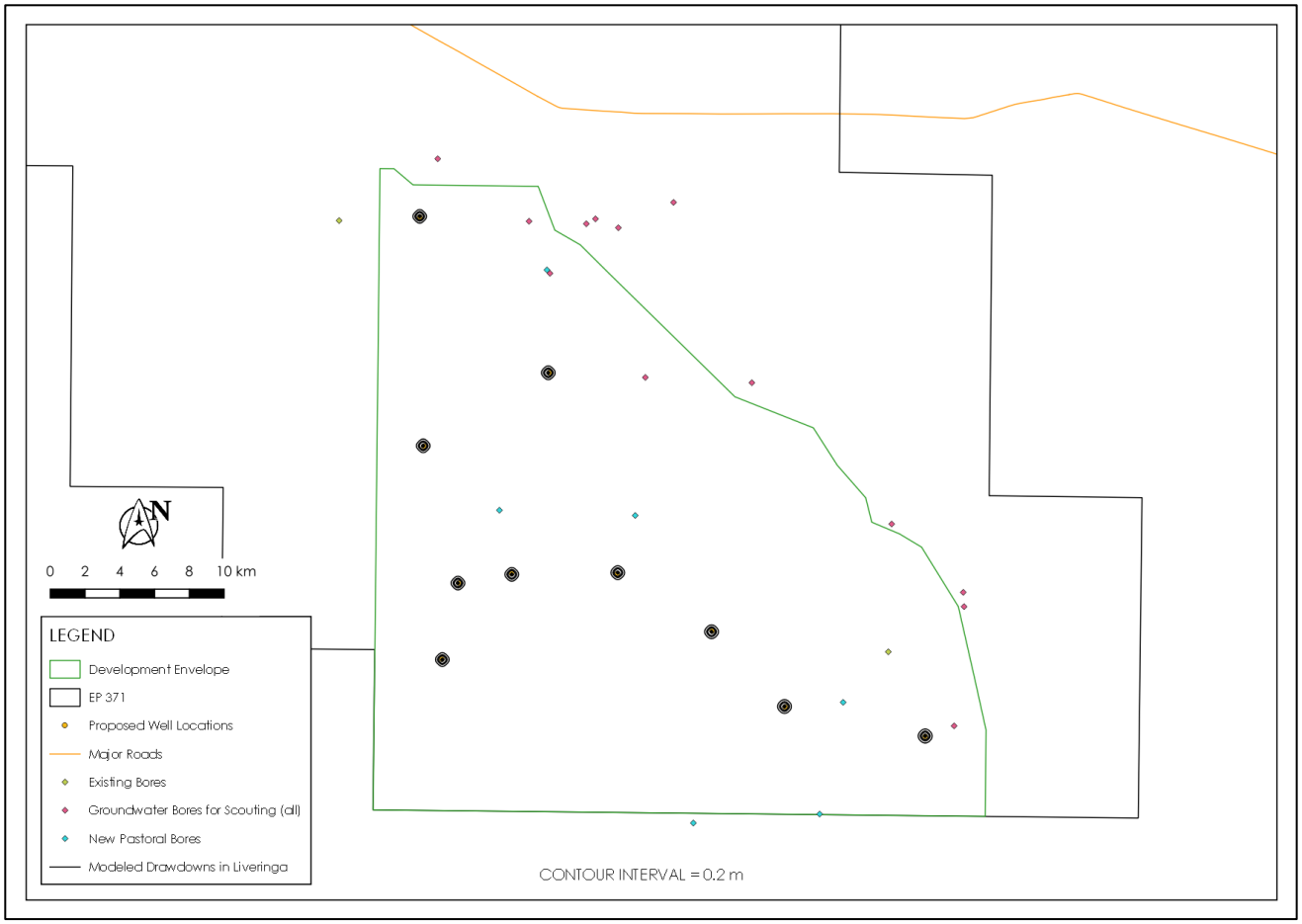

Figure 2-2: Mod 1 model results presented as drawdown contours after six months of pumping, with contour interval = 0.2 metres (Intera model)

Figure: Mod 2 model results presented as drawdown contours after six months of pumping with contour interval = 0.2 metres (Intera model)

The results from Mod 1 indicate that abstraction of the required water volumes will not result in any noticeable impact to existing bores, and that the nearest GDE (Mount Hardman Creek or the Fitzroy River) are too far to experience any significant impacts.

The results from Mod 2 indicate that abstraction of the required water volumes from the Grant/Poole aquifer system would potentially induce temporary drawdowns of between 0.2 and 0.4 metres, and that these would likely recover within a year after the end of the pumping period. The impacts represent a very small percentage of the available water column in each well and would likely not induce any economic impact on existing wells.

Note, this model was considered conservative, as it assumed all rig supply bores to pump concurrently, which was unlikely to happen. In addition, recharge was not included in any of the model simulation.

2.4.4 Key assumptions and uncertainties

In accordance with EPA (2021), key assumptions or parameters that are used to support any numerical modelling are to be described in the GWMP. Specifically, key assumptions and uncertainties used in numerical groundwater modelling to understand the potential for water level drawdown associated with the Proposal are detailed in Table 2-5.

Table 2-5 Key assumptions and uncertainties

Number	Assumptions and Uncertainties	Comment
1	Number and location of extraction bores	BNR plans to install two extraction bores at each well site. Although modelling is based upon a single bore, abstraction bores are anticipated to either alternate or draw with reduced rates such that modelling from a single bore provides a conservative worst-case scenario.
2	Volume of water required to be extracted for the Proposal	The conservation maximum volume of water per well site is estimated to be 100 ML. Modelling volume was less (33 ML) but on review of a much larger number provided in Rockwater (2016) (100 ML), the modelling outcomes are expected to be sufficient to inform the EIA.

2.4.5 Management approach

BNR plans to implement outcome-based indicators under this GWMP. This approach has been determined to be the most appropriate as the outcome can be readily measured with clear thresholds set to enable a level of protection to be achieved.

2.4.6 Rationale for choice of indicators and/or response actions

The indicators proposed are based on the following rationale:

- groundwater modelling indicates that the Liveringa aquifer is in a state of dynamic equilibrium
- groundwater modelling indicates that a drawdown of groundwater is not expected to result in a significant impact to sensitive receptors or other users within proximity of the Proposal
- establishment of outcome-based indicators is achievable, and monitoring of groundwater parameters provide a direct insight into any potential environmental impact arising from the Proposal
- the adaptive management framework enables for clear decisions regarding water extraction to be made where any impacts may be observed. Where additional mitigation is implemented, the timeframe for mitigation to take effect is expected to be relatively short given the dynamic nature and throughflow of groundwater in the region.

A summary of the specific indicators and their justification is provided below.

Groundwater Quality

The DMP and DoW guideline (2016), details a comprehensive list of analytes that is standard for onshore oil and gas projects in WA. Specifically, the guideline recommends that the following criteria be sampled:

- in-field parameters, including water level and dissolved oxygen
- physico-chemical parameters
- ions, including chloride and sulfate
- total metals, including arsenic and chromium
- dissolved gases
- benzene, toluene, ethylbenzene, xylene, naphthalene
- other hydrocarbons.

As the Scientific Inquiry states: An enforceable Code of Practice should include the requirement to test for, and assess the risk from, a comprehensive list of analytes in groundwater, produced and flowback water, including geogenic chemicals and radon, BNR has taken to include the following analytes to be included in the sampling plan:

- radon
- uranium

- geogenic chemicals.

To understand the specific Indicators or Constituents of Potential Concern (CoPC), BNR reviewed the potential environmental impacts and risks as detailed in the Valhalla Gas Exploration and Appraisal Program, Section 38 Assessment – Environmental Review Document (BNR_HSE_MP_013). The Proposal indicates the following fluids as having the potential to impact water quality:

- surface release of drilling fluids and HFS fluids
- subsurface release of drilling fluids
- subsurface release of HFS fluids.

On this basis, the following analytes have been identified for the Proposal to be used as indicators of spill events:

- barium
- cadmium
- chloride
- chromium III
- sulfate
- Total Petroleum Hydrocarbons (TPH)

BNR reviewed the Assessment and Management of Contaminated Sites: Contaminated Sites Guidelines (DER 2014), to identify various health screening levels (Table 2-6). However, given the absence of health screening levels for most constituents, BNR has opted to utilize a before and after impact analysis for the data of these indicators. This ensures that should local geology impact water quality, the collection of baseline samples will enable historic averages to be collected and simple average / standard deviation analysis be utilized to understand water quality variance.

Table 2-6: Groundwater Health Screening Levels

Analyte	Indicators
barium	-
cadmium	-
chloride	-
chromium III	-
sulfate	500 mg/kg (DER 2014)
TPH (C10-C14)	-
TPH (C15-C18)	-
TPH (C6-C9)	-

Groundwater Levels

As detailed in Section 2.4.3, groundwater levels fluctuate naturally between 0.2 to 1 m (depending on the frequency and magnitude of recharge events). For an overview of groundwater depth over the course of historic groundwater monitoring, refer to Appendix H of the Environmental Review Document (BNR_HSE_MP_013).

Consequently, BNR has adopted a trigger / threshold indicator of 1 m for groundwater level as historical data indicates natural variation of up to 1 m is present within the Development Envelope.

3 GWMP components

This section of the GWMP identifies the legal provisions (components) in Table 3-1 that BNR will implement to ensure that the environmental outcomes are met during the implementation of the Proposal.

In accordance with the guideline “Instructions on how to prepare Environmental Protection Act 1986 Part IV Environmental Management Plans” (EPA 2021), this section identifies the indicators that will be used to measure performance and the monitoring that will be undertaken in relation to these indicators. It defines the response actions (trigger level and contingency actions) that will be undertaken if the indicators are exceeded. Table 3-1 details the components of this plan, including monitoring and reporting commitments. Further information regarding monitoring has been described in Section 3.1.

BNR will update Table 3-1 in consultation with both the Department of Water and Environmental Regulations and the Department for Energy, Mining, Industry Regulation and Safety prior to implementation of any drilling activity. This will include the review of trigger and threshold criteria following the completion of wellsite specific baseline sampling.

Table 3-1: GWMP components

EPA factor/s and objective/s	**Inland Waters** – To maintain environmental quality and to minimise the risk of environmental harm, so that environmental values are protected			
GWMP outcome/s	• no long-term changes to groundwater levels • no short or long-term changes to groundwater quality			
Key environmental values	• Liveringa, Reeves and Grant Aquifers • the Groundwater Dependent Ecosystem (GDE) Mount Hardman (associated with the Liveringa Aquifer) • other groundwater users (pastoral stations and fixed receptors >18 km away from the Development Envelope).			
Key impacts and risks	• changes to groundwater levels • contamination of groundwater from surface and subsurface spills			
Indicators	**Response actions**	**Monitoring**	**Frequency**	**Reporting (Section 0)**
GWMP outcome – No long-term changes to groundwater levels **Trigger criteria** Groundwater level measured at defined monitoring locations (Table 3-2) exceed historical average groundwater level values of 0.7 m. **Threshold criteria** When the groundwater level, measured at defined monitoring locations (Table 3-2), exceed historical average groundwater levels of 0.7 m over two consecutive monitoring events which are attributable to the Proposal.	**Trigger level actions** • determine whether the water quality changes observed in the impact sites are comparable to baseline sampling [Note 1] • identify the reason for the change in water quality or groundwater levels and determine direct correlation to the Proposal activities or natural variation and review management measures with an adaptive management response. This may include cessation of groundwater pumping until levels return to their historical average levels and an increase in data collection and monitoring • re-examine water quality or groundwater level monitoring results (QA / QC) to validate data • where the threshold exceedance was not caused by the Proposal, resume standard water quality or groundwater level monitoring frequency • where the water quality or groundwater level threshold exceedance was caused by the Proposal, take steps to remedy the impact (for example cessation of pumping) re-monitor and increase monitoring frequency to monthly. **Threshold contingency actions** Initiate implementation of contingency measures including: • ground truth the water quality monitoring results to validate findings of the assessment and/or determine/identify what may be causing the exceedance. Where cause is identified during ground truthing and can be rectified, undertake action immediately. For actions which require alternate resources, schedule works to be undertaken as soon as possible	Refer to section 3.1	Refer to section 3.1	Routine reporting – Annual Compliance Assessment Report to the DWER Compliance Brach Exceedance reporting to DWER Compliance Branch – exceedance of the threshold criteria and contingency actions that have been implemented – within 5 days.

GWMP outcome – No short or long-term changes to groundwater quality	**Trigger criteria** Changes to groundwater quality at defined monitoring locations (Table 3-2) attributable to the project where they meet the following conditions: • 2 out of 3 successive samples fall outside the mean ± 1 Sigma (SD) limit • 4 out of 5 successive samples fall outside the mean ± 1 Sigma (SD) limit • 8 consecutive points on the same side of the mean. **Threshold criteria** Changes to groundwater and surface water quality at defined monitoring locations (Table 3-2) attributable to the project where they meet the following condition: 1 sample falls outside the mean ± 2Sigma (SD) limit.	• where the water quality or groundwater level threshold exceedance was not caused by the Proposal, resume standard monitoring frequency • where the threshold exceedance can be attributed to the Proposal activities: ○ implement adaptive management response (modified abstraction) management guidance within Section 4. This may include: • for groundwater level - ceasing abstraction, and sourcing water from other sources or reducing abstraction volumes • for groundwater quality - ceasing the petroleum activity to enable source of release to be investigated and mitigated ○ once response actions have been completed, extend the monitoring program and increase to monthly until groundwater quality and level values recover ○ continue to implement actions to remediate the exceedance until approval to cease has been given by the relevant regulator.	Refer to section 3.1	Refer to section 3.1	Routine reporting – Annual Compliance Assessment Report to the DWER Compliance Brach Exceedance reporting to DWER Compliance Branch – exceedance of the threshold criteria and contingency actions that have been implemented – within 5 days.

Note 1: Historical (regional) data available for both the Liveringa and Grant aquifers indicates that groundwater chemistry influenced by the geology is stable with limited variability over the sampling lifetime. Consequently, BNR will compare the variation of regional data with six-months of local baseline data to validate the expectation that the groundwater chemistry at the wellsites is comparatively stable with limited variance. This will be completed using a control charting methodology utilising key constituents, which will be:

- barium
- cadmium
- chloride
- chromium III
- sulfate
- Total Petroleum Hydrocarbons (TPH)

Regional data will be utilised to determine long-term geochemistry variation (mean and utilising standard deviation analysis), this will then be applied to local baseline data. Where the variance is not statistically significantly different to variance displayed by regional constituents, the drilling activity (and surveillance sampling) may commence. Where variance is statistically significantly different to regional constituents an additional six months of local baseline sampling will be implemented (and the control chart methodology repeated following completion of the additional six-month sampling program). On completion of this variance analysis, a report will be sent to DWER and DEMIRS seeking endorsement for BNR to cease baseline sampling and commence the activity (and surveillance sampling).

3.1 Groundwater monitoring program

To clearly understand if the indicators (trigger and threshold criteria) have been met or exceeded, BNR has developed a groundwater monitoring program (Table 3-2) to be implemented over the life of the Proposal and following decommissioning/site reinstatement. This includes groundwater monitoring. Specifically, the monitoring program will be used to:

- establish if local site conditions are unique to those established by historic control sites (prior to well activities commencing) this will be achieved by constructing at least two monitoring bores at each well site, in addition to one monitoring bore into the Grant aquifer in the project area and collecting data prior to drilling of wells. These data will be analysed in conjunction with already held data from the Yungngora Community bore (YG2/18) and the four former Buru monitoring bores discussed in the ERD to establish updated baseline data
- establish duration and frequency of surveillance monitoring prior to well construction, for the duration of the Proposal and following decommissioning
- inform termination criteria for groundwater sampling.

Table 3-2: Groundwater monitoring program

Overview	BNR has developed this monitoring program to collect and analyse local groundwater quality at all well sites associated with the Proposal located within the Development Envelope.
Relevant guidelines	• Guidelines for groundwater quality protection in Australia: National Water Quality Management Strategy, Department of Agriculture and Water Resources (Australian Government 2013) • National Water Quality Management Strategy. Australian and New Zealand Environment and Conservation Council / Agricultural and Resource Management Council of Australia and New Zealand (ANZECC / ARMCANZ) (Australian Government 2018) • Health screening levels for petroleum hydrocarbons in soil and groundwater. Technical report No. 10. Australian Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (Friebel and Nadebaum 2011) • Guideline for groundwater monitoring in the onshore petroleum and geothermal industry (DMP & DoW 2016) • Environmental Factor Guideline – Inland Waters (EPA 2018) • National Environment Protection (Assessment of Site Contamination) Measure 1999. Schedule B1, as amended 16 May 2013 (National Environment Protection Council 2013) • National Water Quality Management Strategy Australian Drinking Water Guidelines (NHMRC and NRMMC 2011 (updated March 2021)) • Contaminated Sites Groundwater and Surface Water Chemical Screening Guideline. Western Australian Department of Health (DoH 2014) • *Water Quality Protection Note 30* (WQPN 30), Department of Water (Western Australian Government 2006, updated August 2023) • Minimum Requirements for Water Bores in Australia (National Uniform Drillers Licensing Committee 2011).
Purpose	To determine if the Proposal has had any adverse impacts to groundwater quality and groundwater levels during its implementation.
Monitoring approach	**Sampling location:** • each well site will have two monitoring bores installed[1] for each location similar to that provided in Figure 3-1 that is : o one at least 10 m down-gradient of the produced formation water evaporation pond

[1] Installation and drilling of all water bores (including abstraction bores) will be hydrostratigraphically logged in detail and geophysical interpretation of groundwater quality collected, for the interval where fresh aquifers are known to be present (including through the Grant formation). Annulus seals and gravel packs will be used, where necessary, to isolate the zone being monitored and prevent potential cross contamination via the bore casing as required by the Minimum Requirements for Water Bores in Australia (National Uniform Drillers Licensing Committee 2011) required to be followed as detailed in the Groundwater monitroing in the onshore petroleum and geothermal industry guideline (DMP & DoW 2016). BNR will conduct validation water samples (along with QA/QC samples of any fluids / water used for the bore installation process) at a point of discharge from the circulation system to understand if cross contamination may be occurring as evidenced by fluid constituent presence associated with bore installation. This may involve the use of tracer dyes, but these specifics are subject to local conditions, aquifer depths and will be direct by a hydrogeologist during bore installation.

	○ one further downgradient of the petroleum well, with the final location determined once site specific information has been gathered. They may be located up to one kilometre down gradient • the location of the bores has been selected to coincide with different perceived risks (i.e., a surface release from the evaporation pond) or a migration of fluids through a fault to the Liveringa Aquifer • the location of the bores will be identified in consultation with DWER and DEMIRS • in addition, one bore will be installed into the Grant Aquifer • all of the bores will be constructed in accordance standards set in WQPN 30. **Sampling frequency – Baseline:** • samples will be collected monthly, at least six months prior to conducting the HFS activities at each individual well site. This frequency is considered suitable and is at a higher intensity than stated in the DMP and DoW guideline (2016) which states that quarterly sampling is considered adequate for monitoring where the general objective is to track any deviation from the baseline condition over time • samples will be compared to those undertaken at the baseline control sites (DMP & DoW 2016). **Sampling frequency – Surveillance:** • during proposal implementation, samples will be collected quarterly, for 12 months. Following this period, where no significant variation from baseline is identified, the sampling frequency will drop to twice a year, and continue following decommissioning/site reinstatement until the termination criteria is achieved • where changes are identified, the frequency of sampling may be increased, and additional groundwater sampling bores installed (as required) to gain a clear understanding of any potential impact • sampling will be increased during HFS activities and for six months following the completion of these activities. Where no significant variation from baseline is identified, sampling will then revert to quarterly. **Analysis:** • as per the DMP and DoW guideline (2016), a comprehensive list of analytes will be sampled including: ○ in-field parameters, including water level and dissolved oxygen ○ physico-chemical parameters ○ ions, including chloride and sulphate ○ total metals, including arsenic and chromium ○ dissolved gases ○ benzene, toluene, ethylbenzene, xylene, naphthalene ○ other hydrocarbons. ○ radon ○ uranium ○ geogenic chemicals • surveillance samples will be compared to both local baseline samples and baseline control sites to determine if there are changes to the groundwater that could be attributed to the Proposal.
Termination criteria	Surveillance monitoring at each individual well site will be terminated following data collection of at least four consecutive sampling events following decommissioning where: • chemical/hydrocarbon constituents are below relevant benchmarks or guideline values or have returned to within the expected natural dynamics of baseline state and/or control sites.

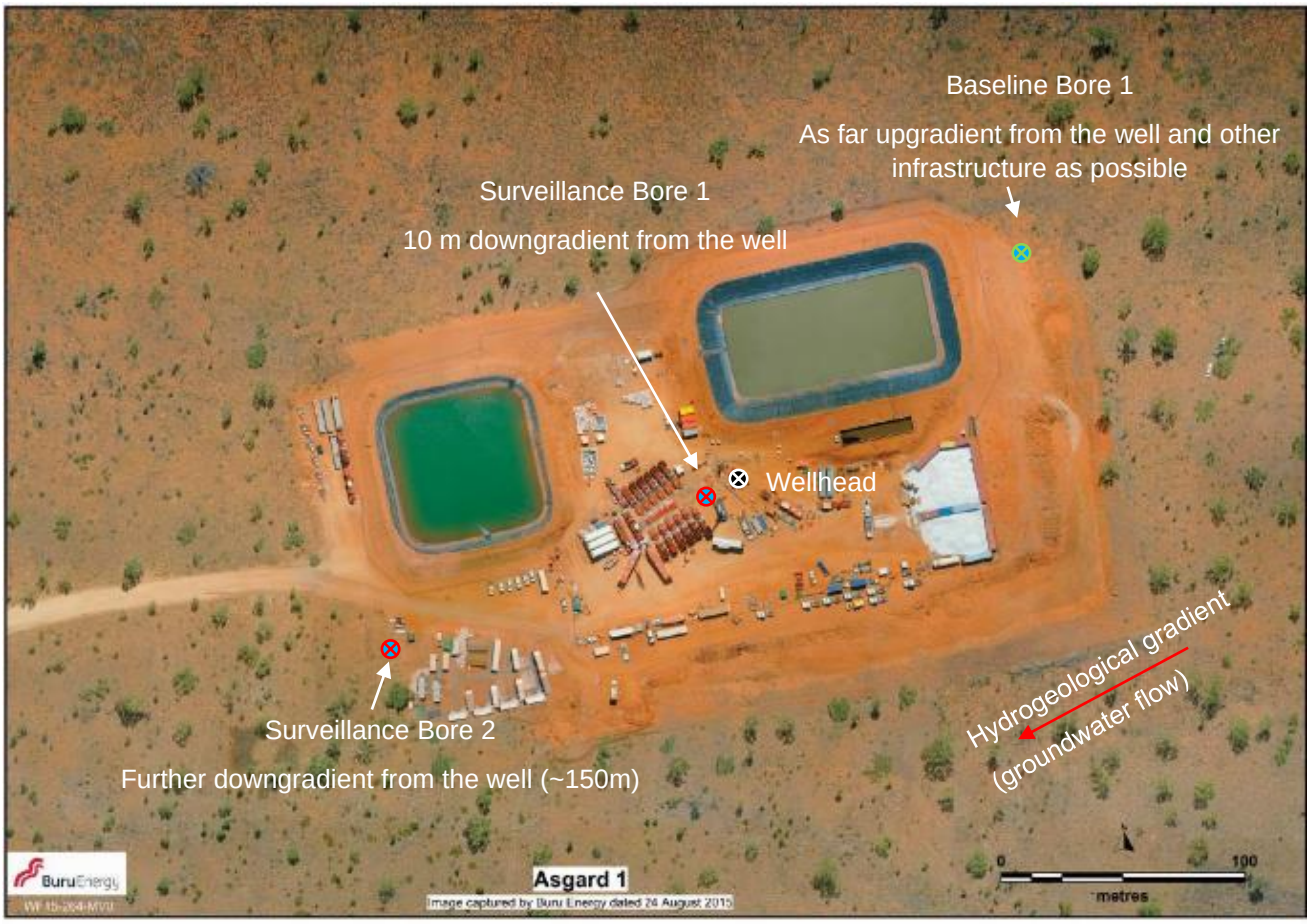

Figure 3-1: Indicative placement of baseline and surveillance bores having regard to wellsite layout

Note, figure 3-1 shows an indicative placement of monitoring bores and shows a wellsite layout with two rectangular ponds. Note that the likely site layout for this Proposal will include an L-shaped pond.

3.2 Reporting

The environmental outcomes will be routinely reported in the Part IV Compliance Assessment Report. This report will include:

- an overall statement of compliance with this GWMP
- analysis against the trigger and threshold criteria (Table 3-1) for each year
- declaration of compliance status against each of the requirements detailed in the Groundwater Monitoring Program
- a description regarding the effectiveness of any adaptive response actions that have been implemented.

In the event that threshold criteria are exceeded during the annual reporting period, exceedances will be reported to the DWER compliance branch within five days.

4 Adaptive management and review of the GWMP

4.1 Monitoring and adaptive management

A monitoring program (as defined in Section 3.1) is required to measure the effectiveness of the response actions as defined in this GWMP. The outcomes of the monitoring program will contribute to ongoing improvements in response actions to ensure an adaptive management approach is adopted.

BNR will implement an adaptive management framework that allows BNR to adapt and implement improvements as a result of monitoring against trigger and threshold criteria detailed in this document.

The following approaches will apply:

- monitoring data will be systematically evaluated
- the effectiveness and relevance of trigger level and threshold contingency actions will be evaluated to determine if any changes to response actions are required
- increased understanding of the hydrogeological regimes based on additional internal and external studies will be incorporated into the monitoring and management approach when newer relevant information becomes available where applicable.

Adaptive management practices that will be assessed as part of this approach may include:

- evaluation of the groundwater monitoring program, data and comparison to baseline data and reference sites on an annual basis to verify whether responses to project activities are the same or similar to predictions
- evaluation of assumptions and uncertainties of the management and monitoring program
- re-evaluation of the risk assessment and revision of risk-based priorities as a result of monitoring outcomes
- review of data and information gathered over the review period that has increased understanding of site environment in the context of the regional ecosystem
- assessment of changes which are outside the control of the project and the response actions identified.

4.2 Management plan review

This GWMP is intended to be dynamic and may be updated to reflect changes in management practices and the natural environment over time. Specifically, this GWMP will be reviewed and updated (as required):

- following completion of baseline monitoring and prior to commencing surveillance monitoring to ensure that the trigger and threshold criteria are updated in consultation with DWER
- annually
- and each time a new Environment Plan (under the *Petroleum and Geothermal Energy Resources Act 1967*) is approved.

This approach will allow flexibility to adopt new approaches / management measures. The effectiveness and relevance of trigger level and threshold contingency actions will be evaluated on an annual basis, and any amendments to response actions will be completed on an as-needed basis. This will include:

- amendment of response actions that are not achieving the desired outcomes
- monitoring that identifies additional impacts requiring additional response actions or changes to existing response actions
- changes to relevant legislation that may affect the implementation of response actions
- improvements to management practices to achieve a greater environmental outcome

- updates to trigger and threshold criteria following the completion of baseline sample collection prior to commencing any groundwater extraction.

Specifically, a table summarising the changes following the template provided as Table 4-1 will be developed. This table will clearly indicate location and reason/s for changes. A tracked change version of the revised GWMP will be provided for all minor, non-structural changes to the document.

Table 4-1: GWMP review template

Complexity of changes	Minor revisions ☐	Moderate revisions ☐	Major revisions ☐	
Number of key environmental factors	One ☐	2-3 ☐	> 3 ☐	
Date revision submitted to EPA	DD/MM/YYYY			
Proponent's operational requirement timeframe for approval of revision	< One Month ☐	< Six Months ☐	> Six Months ☐	None ☐
Reason for Timeframe				

Item number	GWMP section number	GWMP page number	Summary of change	Reason for change
1.				
2.				
3.				

5 Stakeholder consultation

Consistent with the EPA's expectations for this GWMP to align with the principles of EIA, BNR consulted with stakeholders, including the Department of Water and Environmental Regulation (DWER), during the development of the EPA referral. Engagements relevant to this GWMP are presented below in Table 5-1.

Table 5-1: Stakeholder engagement relevant to this GWMP

Stakeholder	Method of engagement	Date of engagement	Summary of engagement
Department of Communities	Email	08 Nov 2021	Enquired if the Yungngora Community groundwater bore data for the Poole Sandstone aquifer (provided by the Department) could be made publicly available in the ERD. The Department declined. As an action, BNR have compared the data and instead summarised similarities/differences without disclosing any data.
Department of Communities	Email	09 Jun 2021	Requested drinking water data from the groundwater bores monitored at the Yungngora Community, to obtain information from the deeper aquifers.
DWER	Meeting	09 Jun 2021	Continued discussion regarding the proposed groundwater monitoring program. DWER requested that background information on the underlying Poole Sandstone and Grant Group aquifers should be included in the ERD.
EPA	Phone	04 Jun 2021	Discussed baseline monitoring requirements from the draft ESD, and requested to remove the requirement to sample at each well site for a period of 24 months, and change to sampling representative control sites for a period of 24 months.
DWER	Phone	03 Jun 2021	Arranged a meeting to discuss DWER's feedback on the proposed Valhalla baseline groundwater monitoring program.
DWER	Email	26 May 2021	Discussed the suitability of the Valhalla baseline groundwater monitoring program, with regard to monitoring control sites only within the Liveringa Aquifer. Questioned that the other deeper aquifers must be discussed.
Noonkanbah Station manager	Phone	13 May 2021	Discussed the availability of bore logs from pastoral bores on the station; unofficial bore logs could be made available. Re-confirmed that BNR could sample water from the pastoral bores by unscrewing pipes or opening taps. Mentioned that access roads and fence line tracks would be graded at the end of May, and mustering activities would commence early June.
Blina Station manager	Phone and email	23 Mar 2021	Discussed sampling station bores for the baseline groundwater monitoring program – station accepted. Discussed the availability of a bore log for a bore located on Blina Station. Confirmed that BNR could sample water from that bore by opening the tap.
DWER	Email	22 Mar 2021	Reviewed sampling methodology and locations for baseline control site groundwater monitoring program. Enquired about availability of bore logs and any existing data for any pastoral bores.
Noonkanbah Station manager	Phone and email	08 Mar 2021	Discussed sampling station bores for the baseline groundwater monitoring program – station accepted. Enquired about the availability of bore logs from pastoral bores on the station. Confirmed that BNR could sample water from the pastoral bores.

For a full summary of stakeholder engagement records refer to the BNR Environmental Review Document (BNR_HSE_MP_013). Any additional consultation regarding this GWMP will be captured in subsequent revisions.

6 References

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